DESCRIPTION OF MODEL

Appendix B describes the ASPIC (production) model and results that were presented at the first STAR panel (May 2007) in Portland, OR. Additionally, a comparison of depletion and stock biomass between the ASPIC and SS2 models were included in response to a request from the Mop-Up STAR panel (October 2007) in Seattle, WA. Overall, the general trends are very similar; however, the ASPIC model results in higher estimated productivity when compared to the results of the SS2 model. The strong similarities between the two model results suggests that alternative modeling approaches may be appropriate for stock assessments with limited data.

Stock Synthesis II

We developed a size- and age-structured model using Stock Synthesis 2 (ver_ 2g) (Methot 2005) to model the population dynamics of the blue rockfish stock in California, north of Point Conception. The Stock Synthesis model estimates and projects the survival, growth and reproduction of individual age classes and incorporates ageing errors and variation in growth. It allows a variety of data types to be combined and used to estimate parameters in one formulation. The data and control files for the final base model can be seen in Appendices C and D.

Based on maximum ages of 41 (females) and 44 (males) (Laidig et al. 2003) and Hoenig (1983), natural mortality was initially assumed to be M = 0.10 for males and females in the base model. During the review process, the under-representation of males in the fishery data was consistent in all model runs. To try to capture this, a range of values for M and male offsets for M were explored, and male M was fixed at 0.12 in the final base model with female M remaining fixed at 0.10.

Considering the recommendation based on the meta-analysis by Martin Dorn (NMFS/AFSC, pers. comm.), steepness (*h)* was fixed at 0.58. Recruitment was estimated from 1960-2006. The logistic selectivity function was used for each fishery and survey, with a male offset also estimated from the recreational data. A convergence criterion of 0.00001 log-likelihood units was used for all runs of the model.

The final base model included the historical catch series from each fishery, conditional age-at-length compositions from the recreational CPFV fishery (1980-1984), length compositions from the recreational (RecFIN, CDFG onboard observer survey, 1980s CPFV) and commercial (hook and line and setnet) fisheries, two recreational CPUE indices (RecFIN separated pre- and post- bag limit change in 2000 and CDFG survey) and a pre-recruit index (2001-2006). We assumed equal likelihood weights (= 1.0) for all data sources. There were very few samples (n<10) in the commercial setnet fishery, so we used the length compositions only to determine the selectivity and did not tune between model runs. Since the recreational fishery did not have any sex information available for the length compositions, we used the sex-specific age compositions from the 1980s to determine the selectivities for this fishery. We set a male offset to help in estimating the differences in selectivity between the sexes. In every data source we explored for this assessment, females were selected much more (70-80%) than males. Depth is one potential factor that could be contributing to this selection. In three observed occasions, male numbers were greater than or equal to female numbers in depths <12 fathoms (Don Pearson, NMFS/SWFSC, pers. comm.)

The growth parameters of k and L_{max} were estimated in the final base model, with L_{min} remaining fixed at the externally estimated value (Figure 45). Prior to the Mop-Up STAR panel, we estimated growth outside of the model (Figures 46, a-b) using the combined area data from the 1980-1984 CPFV age and length data, as well as dive data (young fish, ages 1-3) provided by Tom Laidig (NMFS/SWFSC). External fits of the Schnute (1981) parameterization of the von Bertalanffy growth equation were the following: female parameters - t_1=2 (years), L_1=17.9 (cm FL), t_2=25 (years), L_2=37.5 (cm FL) and k=0.147 (n= 2340, CV=0.089); male parameters - t_1=2 (years), L_1=15.7 (cm FL), t_2=25 (years), L_2=31.2 (cm FL) and k=0.295 (n=667, CV=0.108).

The age composition data was limited in this assessment to samples collected in the recreational fishery between 1980 and 1984. These data were fitted as conditional age-at-length data, in which length and age observations are analogous to entries in an age-length matrix with ages in the columns and lengths in the rows. This approach was implemented in SS2 in order to improve the ability to fit growth curves internally and avoid problems associated with weighting of the length and age likelihood components, particularly when age structures are collected as a subset of the measured fish (Stewart 2006; Helser et al. 2006; Punt et al. 2006). For blue rockfish, conditional age-at-length data represent individual fish rather than expanded age-at-length compositions, as the latter could not be derived from the recreational samples. Initial multinomial sample sizes were the number of trips sampled for each year, with this effective sample number partitioned among the length bins (rows) for any given year based on the fraction of aged fish in that length bin for that year (Figures 47, a-b). The same age composition data were included as traditional age composition data in the data file with no emphasis values in order to graphically illustrate the relative (marginal) fits to the data, a useful diagnostic for more rapidly evaluating the relative fit to all of the data and the improvement in fit gained by freeing (rather than fixing) growth rate parameters in particular.

Model results

The total number of parameters estimated was 74, including the unfished equilibrium recruitment (R_0), eight parameters for logistic selectivity curves (two surveys and two fisheries), four parameters for growth curves (L_{min} was fixed) and 47 recruitment deviation values (for the years 1960-2006). Male offset parameters for selectivity were estimated based solely on the recreational age composition data that included early 1980s CPFVs and then fixed for all fisheries, as these were the only data that had clearly identified catches to sex (and which illustrated that males were much less frequently encountered than females). Table 21 provides the point estimates for these parameters, as well as the model estimated standard deviations. The base model estimates of summary biomass (age1+), spawning biomass, recruitment, total catch, exploitation and depletion are provided in Table 22.

All results shown and discussed are relative to a base model with the same parameter configuration as the final model in which the assumed sample sizes and survey CVs were tuned to the effective sample sizes and CVs output from initial model runs. Tuning was conducted using the variance adjustment factor vectors available in SS2, such that variance was added to survey index CVs, and multipliers were used to scale the effective sample sizes for length and age composition information. The length composition information for the setnet fishery is based on extremely low sample sizes, and the length information was solely intended to provide a selectivity curve, so this index was not tuned to reflect the "more informative" effective sample sizes reflected by the model. All other indices and composition information were tuned to the point where the ratio effective and the input CVs/sample sizes were close to one.

The model estimated an unfished spawning biomass (SSB_0) of 2077 million larvae, an unfished summary biomass of 13,222 mtons and a 2007 spawning biomass of 622 million larvae, which results in a relative spawning biomass estimate of 0.297 in 2006. The depletion level at its lowest point (1994 and 1995) was estimated to be 205 million larvae, or 10% of SSB_0. Figures 48 (a-b) show the total spawning biomass and depletion (with reference 25% and 40% of unfished biomass). The highest exploitation rates (and greatest relative population declines) seemed to occur from the 1970s through the 1990s, (Figures 49 a-b). In recent years, fishing mortality rates have been close to the current target SPR of 50% but the biomass is below target levels. The model estimated proxy MSY based on an $F_{50\%}$ SPR is 275 metric tons. This value is associated with an exploitation rate (catch over summary biomass) of 0.06, and an equilibrium spawning output of 831 million larvae, which corresponds to 40.0% of the unfished larval production.

Although the length data are aggregated by sex and there are no clear modes visible in evaluating the length compositions with the eye, the model fit improved significantly with recruitment deviations estimated freely (1960-2006). Figures 50 (a-b) show estimated annual recruitment values over the time period with 95% asymptotic confidence limits. Estimated recruitment deviation values and deviation variance checks can be seen in Figures 51 (a-b). Importantly, the variance on most of the recruitment deviation estimates is large, consistent with the general observation that strong year classes are not obvious in the data. This suggests that although there are signs of highly variable recruitment in the data, the actual years of strong recruitment are likely to be poorly specified.

Fits to each of the relative abundance indices (in both arithmetic and log scale) and scatterplots of observed versus predicted indices are shown as Figures 52-55. Some serial autocorrelation is suggested in the residuals to the fits to the two recreational CPUE time series, although the fits capture the general trends reasonably well and are comparable to the type of fit often achieved to relatively noisy recreational CPUE time series. The fits to the pre-recruit survey should be interpreted with caution as there is essentially no available data to conflict with the survey predictions of year class strength. As this dataset is of short duration and the “core area” (longer time series) failed to capture the magnitude of the 1999 year class, the results should be treated with caution. This is particularly true as the model predicts the 2001-2006 recruitments to be considerably lower than previous years; the explanation for this is unclear. However, the overall effect of including the juvenile abundance dataset is negligible with respect to estimates of reference points and biomass trend through the present period.

The estimated selectivity (length-based, sex-specific) curves for each fishery and survey are shown as Figures 56-57. Fits to catch at length data by fleet and Pearson residual plots are shown as Figures 58-63. Fits to the catch-at-length data for the recreational fishery (fleet 1), the hook and line fishery (fleet 2) and the recreational onboard observer program (fleet 4, treated as a survey) are generally quite reasonable, although as noted previously there is little obvious suggestion of the strong year classes that are estimated in the recruitments. The setnet fishery (fleet 3) had extremely sparse data, and the length data that are included were included solely for the purpose of fitting the selectivity curve.

The fits to the conditional age-at-length data are shown as Figures 64-68, with the residuals shown as Figures 69-71 and the assumed and effective sample sizes of the (tuned) conditional data shown as Figures 72 (a-b). Freeing the growth parameters improved the fit to the age and length data significantly relative to the externally estimated values (approximately 120 likelihood units), primarily through the effect of reducing the K growth coefficient in order to slow the growth and better fit to the age-at-length information. However, the relative contribution to informing strong or weak cohorts was modest, as illustrated by the marginal fits to age composition data (representing the conditional age-at-length data in a more traditional format by using a “ghost” fishery and mirrored selectivity to fleet 1, the recreational fishery). This is consistent with the observation that strong cohorts are not readily apparent in either the age composition or the length composition data. This could be due to low recruitment variability, a high degree of ageing error, small sample sizes, or the combination of all of these factors. Fits to catch at age data for the early 1980s recreational data improved considerably with the changes made during the Mop-Up STAR panel (Figures 73, a-b).

Sensitivity Analysis

Prior to the Mop-Up STAR panel (no conditional age-at-length, recruitment deviations (recruit devs) estimated from 1980-2006 and M=0.1 for both males and females), a sensitivity test was performed turning off the recruit devs, and the result was a considerably poorer fit to all of the sources of data (indices, catch at length, and interestingly even catch at age from the period prior to which recruit devs were estimated). The model result without the recruit devs freely estimated was considerably more pessimistic, and suggested that the stock is below the overfished threshold. Interestingly, exclusion of the age data gave a similar (although not as extreme) result, with a more pessimistic assessment of stock status. By contrast, when both of the CPUE time series and their associated length data were removed, the results were considerably more optimistic.

Also, likelihood profiles were developed for both steepness and natural mortality, and were shown graphically as relative likelihoods for the total fit as well as the separate components (indices, length composition data, age composition data). The overall likelihood was minimized at a relatively low steepness value (~0.3), which was strongly influenced by the age and length composition information; the relative abundance indices favored a higher value (~0.5) but were less influential in the model fit. (Note: results are different from the final base model after the Mop-Up panel.) Similarly, a considerably lower natural mortality rate provided an improved fit to the age composition information, a moderately lower natural mortality rate improved the fit to the length composition information, and the fits to the indices were consistent with the base model estimate of 0.1. The model results were considerably more sensitive to changes in the estimate of natural mortality, with the model suggesting that the current biomass was well above the unfished equilibrium biomass level when a higher natural mortality rate was assumed, and suggesting considerably greater depletion when a lower rate was assumed.

During the Mop-Up STAR panel, numerous sensitivities were performed to refine the specifications of the base model. Starting year for estimating recruit devs was evaluated in 5 year increments from 1940 to 1980. The starting value for recruitment deviations was set to 1960, which was approximately the year that data began to be informative about year class magnitude.

A sensitivity was also conducted to determine σ_R . Initially, σ_R was set at 1.0 but was believed to be too high and allowed for too much variability in recruitment. Values ranging from 0.5 (likelihood 1468) to 0.1 (likelihood 1719) were evaluated and the panel recommended setting the base model value $\sigma_R = 0.5$.

A sensitivity early on with low catches (half of BASE) and high catches (double BASE) showed little sensitivity in terminal depletion levels.

Given the evidence of a potential change in growth in blue rockfish over time, we explored a time-varying growth model. The 1980s recreational CPFV data and the sparse 2003-2006 Groundfish Ecology survey data were used to estimate two growth curves for differing time periods. Setting up time blocks (1916-1985, 1986-2006) for growth and selectivity resulted in model instability with the limited amount of age data in the last 20 years.

When the CVs of length at age were internally estimated, the female CVs ranged from 0.07-0.09 and the male CVs ranged from 0.07-0.16. We then let the model estimate CVs for the young and old. Based on the internal estimates just stated and the external estimates (Figures 74, a-b) provided by EJ Dick (NMFS/SWFSC), it was recommended that the CVs for the young males and females be fixed at 0.085. The CV for the old females was fixed at 0.095 and the CV for the old males was fixed at 0.11.

Much effort was put into trying to determine an appropriate estimate for natural mortality (M). The lack of old males in the fishery data could be due to either selectivity or a higher natural mortality for males. The male selectivity curve was estimated to be much lower than females and was dome-shaped due to the dog-leg parameterization of the male selectivity offset. We attempted to explore this formulation, fixing the slope and keeping the shape the same while allowing the level to vary to see if a simple offset to the female selectivity pattern would fit the data just as well. We found that this could not be accomplished in SS2 and was not explored further.

Initially, male and female natural mortality were assumed to be 0.1, based on maximum ages and Hoenig (1983). Throughout numerous sensitivities, improvements in fit with a male M offset were large enough to justify differing M's between males and females. Examples of some of these sensitivities are as follows: estimating male M (0.115), fixing M based on Tenera (2000) estimate of 0.14, assuming a ramp for male M between ages 10 and 20 - estimating young (0.1) and old (0.134) M and then fixing those values. The results of the ramp in male M were ambiguous, but when comparing the likelihood values associated with the initial fixed value of 0.1 (1355), a fixed value of 0.14 (1375) and the model estimated value of 0.115 (1341), the decision was made to fix male M = 0.12, leaving female M = 0.10. Figures 75 (a-b) profile natural morality and steepness for the final base model.

Forecasts

Future catch projections through 2016 were made based on an $F_{50\%}$ fishing rate with 40:10 adjustment. The sum of the average catch from each fishery for the years 2005 and 2006 (263 mtons) were applied to the beginning projection years of 2007 and 2008. The forecasts from the base model predict a slight increase in abundance but not enough to support increased harvesting of blue rockfish in the future. However, the state of nature corresponding to higher natural mortality (M females = 0.13, M males = 0.15) remains above 40% and allows about 370 mtons to be taken in 2009.

Decision Tables

The base model assumes natural mortality (M) for females to be 0.10 and 0.12 for males. To bracket the uncertainty in this assessment, the STAR panel suggested the state of nature to be based on high and low estimates of M with high and low catch streams. The initial request to offset M from the base model was ± 0.02 which gave equal likelihoods (1338) for the base and the higher M scenarios, with the likelihood of the low M scenario being 9 points higher (1347). Considering this did not provide enough contrast to capture the uncertainty, the STAR panel then suggested a ± 0.03 offset for further investigation which was completed after the review. The results of this request proved the likelihood of low M values were even less likely (1361) than the previous offset, and the base and high M scenarios were still nearly the same (Table 23).

For direct comparison, the likelihood values when changing M only (not the catch stream) can be seen in Table 24. In each case, the likelihood for all low M scenarios are much higher, indicating they are not as likely. Even though the STAR panel did not assign probabilities to the states of nature, the STAT feels strongly that the base and high M scenarios are most likely, based on the discussion above and also considering the estimate of M (0.14) provided by Tenera (2000). Table 25 provides all likelihood components for each of the states of nature. Decision tables of 10-year projections (under the 40:10 and 60:20 adjustments) for alternate states of nature and management options can be seen in Tables 26 and 27.